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Search for radio recombination lines towards the gravitational lens PKS 1830-211

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Abstract. A search for radio recombination lines near 20 cm at $z=0.193$ and $z=0.886$ towards the gravitational lens system PKS 1830-211 has yielded upper limits of $|r_L| \leq 5 \times 10^{-5}$ and $\leq 5 \times 10^{-4}$ at the two redshifts respectively. Based on the non-detections, we derive upper limits to the emission measure of the ionized gas in the absorbing systems. We also present continuum flux density measurements over the frequency range 0.3–45 GHz made at a single epoch.

1. Introduction

There is evidence that the gravitational lens system PKS 1830-211 has two absorbers at two different redshifts of 0.886 and 0.193. The main lens, a normal galaxy at $z=0.886$, has been studied in HI, OH and a host of molecular lines (Chengalur, de Bruyn, & Narasimha 1999 and references therein). The only evidence for an additional absorber at $z=0.193$ is from HI absorption (Lovell et al. 1996; Verheijen et al. 1999) studies. Searches for molecular lines at this redshift have been unsuccessful.

2. Observations

Taking advantage of the strong radio continuum of the background source (S_{1.4 GHz} = 10 Jy), we searched for stimulated emission recombination lines at both redshifts, using the VLAA¹ at 20 cm; the H158 α line from the $z=0.193$ system ($\nu_{rest}=1.65$ GHz) using a bandwidth of 1.56 MHz and a velocity resolution of 5.3 km s⁻¹ and the H136 α line from the $z=0.886$ system ($\nu_{rest}=2.59$ GHz) using a bandwidth of 3.125 MHz and a resolution of 21 km s⁻¹. Neither line was detected with 5σ upper limits to $|r_L|$ of 5×10^{-5} and 5×10^{-4} corresponding to $z=0.193$ and $z=0.886$ respectively.

Since this source is highly variable, we used the VLAA to measure the continuum flux density at a single epoch over the frequency range 327 MHz to 45 GHz,

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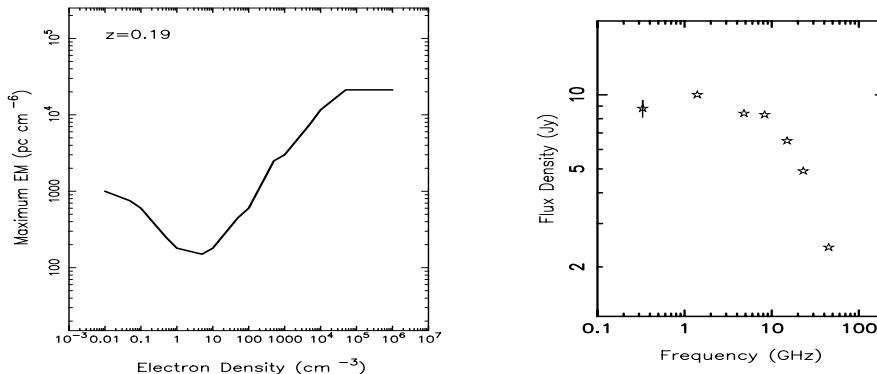


Figure 1. *Left:* The maximum allowable emission measure of the ionized gas in the $z=0.193$ system as a function of its density, based on the upper limit to the H158 α recombination line. *Right:* The measured radio continuum spectrum of PKS 1830-211

to determine the intrinsic spectrum of the background source. The observations were made on 27 Oct, 1997 with 3C 286 as the primary calibrator. Figure 1 (right) shows the continuum flux density as a function of frequency. Assuming that the core radiation at low frequencies has a flat spectrum, we derive upper limits to the free-free optical depth of $\tau_c \leq 0.13$ at 330 MHz. For $T_e=7500$ K, the corresponding upper limit to the beam averaged emission measure is $\text{EM} \leq 4 \times 10^4 \text{ pc cm}^{-6}$ if the gas is at $z=0.193$ and $\text{EM} \leq 10^5 \text{ pc cm}^{-6}$ if the gas is at $z=0.886$.

3. Constraints on the ionized gas at $z=0.193$

Since the HI optical depth in the $z=0.193$ system is the same against both the lensed images of the quasar (Verheijen et al. 1999), we assume that the line emitting gas is uniformly distributed in a slab against the entire continuum source. Figure 1 (left) shows the maximum allowable emission measure of the gas as a function of density that is consistent with the upper limits to the line strength and the continuum optical depth, assuming a line width of 80 km s^{-1} .

Fig 1 shows that our experiment is most sensitive to low density gas ($n_e = 1-10 \text{ cm}^{-3}$) and indicates an upper limit to the *beam averaged* emission measure of 100 pc cm^{-6} for this gas in the $z=0.193$ system. If the line emitting gas is predominantly of density $5-10 \text{ cm}^{-3}$, then the size of such a region located anywhere in the observed beam is constrained to be less than $200-300 \text{ pc}$ in size, assuming a homogenous gas distribution. On the other hand, if the gas is in compact structures with density $\sim 10^3 \text{ cm}^{-3}$, then its beam filling factor is constrained to be less than 6×10^{-4} . Higher resolution observations of the line at comparable sensitivities and the knowledge of the system's inclination angle will greatly improve the constraints on the ISM in the $z=0.193$ absorber. The limits for the $z=0.886$ system are about ten times higher.

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References

- Chengalur, J.N., de Bruyn, A.G., & Narasimha, D. 1999, A&A, 343, L79
 Lovell, J.E.J. et al 1996, ApJ, 472, L5
 Verheijen, M.A.W, Carilli, C., Yun, M.S., & Menten, K. 1999, private comm.